1 OF 1

AD

665 862

Distribution of this document is unlimited

AFTAC Project No. VELA T/ 6708
ARPA Order No. 624
ARPA Program Code No. 6F10

FINAL REPORT

KURILE ISLANDS EXPERIMENT

OCEAN-BOTTOM SEISMOGRAPHIC EXPERIMENTS

Prepared by

Joseph G. McDermott   A. Frank Linville   Terence W. Harley

Ralph R. Guidroz, Program Mana
Telephone: 1-214-238-3473

TEXAS INSTRUMENTS INCORPORATED
Science Services Division
P.O. Box 5621
Dallas, Texas 75222

ACKNOWLEDGMENT

This research was supported by the
ADVANCED RESEARCH PROJECTS AGENCY
Nuclear Test Detection Office,
under Project VELA UNIFORM,
and accomplished under the technical direction of the
AIR FORCE TECHNICAL APPLICATIONS CENTER,
Contract No. F33657-67-C-0105-P002

Effective Date of Contract: 28 July 1966
Contract Expiration Date: 27 April 1967
Amount of Contract: $892, 217

30 August 1967

Requests for additional copies by agencies of the Department of Defense, their contractors, or other government agencies should be directed to

DEFENSE DOCUMENTATION CENTER (DDC)
CAMERON STATION
ALEXANDRIA, VIRGINIA 22314

Department of Defense contractors must be established by the cognizant military agency of their project or contract.

All other persons and organizations should apply to the

Clearinghouse for Federal Scientific and
Technical Information (CFSTI)
Sills Building
5285 Port Royal Road
Springfield, Virginia 22151

TABLE OF CONTENTS

LIST OF APPENDIXES

LIST OF TABLES

LIST OF ILLUSTRATIONS

SECTION I

INTRODUCTION AND SUMMARY

An Ocean-Bottom Seismograph Kurile Islands Experiment was conducted between 21 October 1966 and 16 December 1966 under Contract F 33657-67-C-0105. Objectives of the experiment were to determine the operational worthiness of the Ocean-Bottom Seismograph (OBS) and to increase knowledge of seismic velocities, epicenter determinations, microseisms, and seismicity in the area of interest. Results of several special analyses are presented in this report. Other data are found in special reports presented under this contract.[1,2,3,4]

All field objectives were accomplished as planned or modified to satisfy field conditions. Specific results of the Kurile Islands experiment are as follows.

- OBS units are reliable, self-contained, free-fall, remote-recall, deep-ocean instrument packages. Fourteen of 18 units were recovered, and 13 recorded data all or most of the time. Pressure and vertical data were excellent; horizontal data were improved but still showed intermittent resonance. Ability of each unit to detect and record seismic energy is illustrated in the Preliminary Bulletin and its accompanying report.

- Five-ton calibration charges can be packaged at sea and successfully deployed. The calibration program was completed without a misfire.

- The bathymetric data indicate that the shelf margin and slope areas of the Kurile trench are more complex than previously mapped.

- Most events recorded by the OBS network were local or near-regional. The few teleseismic events recorded were located in selected regions, and all had computed magnitude (USC&GS) of 5.5 or larger.

- Usable P_n arrivals from 5.2-ton calibration shots propagated from 0-2° distance (Δ) with 100-percent probability of detection by the OBS units, from 2-4° with 75-percent probability of detection, and beyond 4° with 50-percent-or-less probability.

- Weather movements correlated with noise-amplitude fluctuations, increasing over the whole region during periods of adverse weather (low-pressure disturbances). Noise variations due to weather were so dominant that noise differences due to distance from shore or local topography were difficult to define. Mean noise levels were of the same order of magnitude as those found in previous investigations (150 mμ 0-to-peak in the 0.6- to 1.4-sec period range).

- Analysis of first-arrival data from the 17 explosions and 13 local earthquakes indicated an average crustal velocity of 5.4 km/sec and a mantle velocity of 8.1 km/sec in the Kurile region. Lack of detailed coverage prevented determining velocity variations in the region.

- More problems were caused either directly or indirectly by foul weather than any other factor; in particular, the adverse weather hindered launch and recovery procedures, navigational accuracy, and communications.

Contract F 33657-67-C-0105 was divided into five tasks — shallow-water tests, field operations, preliminary data review, special analysis, and preventive maintenance.

Task I consisted of shallow-water tests near Santa Barbara, California, in September 1966. Of 14 units submerged in 80 ft of water, 13 were either fully operational or required minor corrections. One unit surfaced prematurely, floated inshore, and was damaged on the rocks.

In addition to the routine tests, two special tests were completed. One test used a Rustrak dual-channel recorder placed in each unit to record the temperature of both the inside surface of the sphere and the digital-clock crystal, providing temperature information to assess clock drift. This test showed that the change in crystal temperature lags the sphere temperature change by approximately 1 hr.

A special antenna test indicated that the most mechanically reliable design which would contribute least to unwanted motion of the OBS was a 48-in. fiberglass whip antenna attached to a hinged spring-mounted plate. The antenna folds down against the instrument's side when the unit is on the ocean floor and then erects vertically when the unit surfaces.

Task II was devoted to 78 days of field operations southeast of the Kurile Islands. There were two field-operation phases: the first used a 13-unit network and the second a 5-unit network. Of the 13 units launched during the first operation phase, 9 units were recovered. All 5 units launched during the second operation phase were recovered. In addition, 17 chemical explosions ranging in size from 1.0 to 5.2 tons were detonated.

General position accuracy was estimated to be ±2 mi. Due to generally cloudy skies, only one star fix per day could be obtained. While most fixes were obtained using celestial techniques, radar was used near island positions. Loran data were poor as expected, and Omega stations were off the air for extended periods of time. This lack of continuous navigation capability hindered the operation and was the primary limiting factor throughout the experiment.

Task III was a preliminary data review. Analysis of data revealed that 89 events reported by USC&GS were recorded by the network. Seventy OBS preliminary epicenters were determined from the data, bringing the total number of associated events recorded during the experiment to 176 including USC&GS epicenters and calibration explosions. In addition, 200 assumed associated events were determined, with the number of stations per assumed event ranging from 3 to 7. The majority of epicenters recorded during the 268 days of instrument recordings are located on the northwest side of the Kurile trench.

Special analysis comprised Task IV. From approximately 6000 noise samples obtained, the stations near the islands appeared to have a slightly higher noise level than those stations across the trench to the east. Analyzed to determine the average crustal and mantle P-wave velocities in the Kurile region were data from 17 explosions and 13 local earthquakes with focal depth of 33 km. Average crustal P-wave velocity was found to be 5.4 km/sec, while the mantle average P-wave velocity was 8.1 km/sec.

Under Task V — preventive maintenance — all equipment underwent routine preventive maintenance.

A summary of the project objectives and results is presented in Appendix B. Because of contract limitations on time and funds, not all tasks were completed. Appendix B indicates how much was completed on each objective. As indicated in the appendix, the data warrant more special analysis. Also, to enable identification and elimination of the resonant problems and dead-channel characteristic of the horizontal components, improvement studies should continue.

SECTION II

FIELD OPERATIONS

The OBS Kurile Islands Experiment was conducted between 21 October 1966 and 16 December 1966. Program objectives were to determine the operational worthiness of the OBS and to analyze the data collected in order to

- Prepare a preliminary bulletin which would indicate the seismic activity within the station network
- Make a preliminary estimation of the crustal structure
- Estimate the probable traveltime anomalies and location biases for teleseismic stations
- Study the noise field in the Kurile region

The field operations were conducted in two phases. In Phase I, 13 units were launched as scheduled, nine were recovered, and eight were operated all or most of the time they were on the bottom. During Phase I, 12 explosions (six 1.0-ton and six 5.2-ton) were fired. The Phase II network was modified from 13 to five units because of adverse weather conditions. All five units launched during the second phase of operations were recovered. In Phase II, five explosions (one 1.5-ton and four 5.2-ton) were fired. Tables II-1 and II-2 list pertinent data about the units and explosions, respectively. Figure II-1 shows the operating periods for each unit recovered and locates (in time) the explosion sequences. Approximately 268 days of instrument recording were obtained overall. The maximum number of stations recording at any one time was seven. At least six stations were recording during all explosions of Phase I, and four were recording during all explosions of Phase II. Figure II-2 shows the unit and explosion locations.

Table II-1

OCEAN-BOTTOM SEISMOGRAPH STATION LOCATIONS, KURILE EXPERIMENT

Phase	Station Position	Drop Date	Drop Time (z)	Unit Number	Approx. Water Depth (fm)	Drop Location	*Position Accuracy (mi)
Phase I	S1	21 Oct	18:22	21	400	43°10.5'N, 146°20'E	± 2
	S3	22 Oct	08:32	14	1900	43°26'N, 147°47'E	± 2
	S5	23 Oct	02:37	15	4315	43°40'N, 149°40'E	± 3
	S4	23 Oct	12:33	16	230	44°41'N, 148°29'E	± 2
	S7	23 Oct	23:45	19	1500	45°08'N, 150°31'E	± 2
	S9	24 Oct	11:53	20	3200	45°00'N, 153°00'E	± 2
	S8	25 Oct	02:29	23	1750	46°19'N, 151°22'E	± 2
	S11	25 Oct	10:30	22	1650	46°30'N, 153°00'E	± 2
	S12	26 Oct	00:15	25	2850	46°28'N, 155°11'E	± 3
	S13	26 Oct	11:21	24	1320	47°40'N, 153°50'E	± 2
	S2	28 Oct	08:41	11	3300	42°07'N, 146°59'E	± 3
	S6	6 Nov	17:41	12	2920	41°45'N, 151°46'E	± 3
	S10	6 Nov	11:14	13	3000	43°38'N, 154°35'E	± 5
Phase II	S7A	24 Nov	05:14	24	330	45°21'N, 149°56'E	± 1 5
	S4A	24 Nov	21:00	10	230	44°43'N, 148°30'E	± 1.5
	S3A	25 Nov	22:33	20	600	43°36'N, 147°25'E	± 2
	S1A	27 Nov	04:22	19	900	43°10'N, 146°30'E	± 2
	S5A	2 Dec	01:55	21	3100	43°25'N, 150°17'E	± 2

*Celestial navigation was the primary means of navigation. Position accuracy was based on a best estimate from review of operations log book and data evaluation.

Table II-2

OCEAN-BOTTOM SEISMOGRAPH CALIBRATION EXPLOSION LOCATIONS, KURILE EXPERIMENT

Phase	Position	Shot Date	Shot Time (z)	Charge (tons)	Water Depth (fm)	Shot Location	*Position Accuracy (mi)
Phase I	E11	5 Nov	23:24:03.0	1.0	2206	43°06'N, 148°04'E	± 2
	E9	6 Nov	03:33:03.0	1.0	2300	43°35'N, 148°17'E	± 2
	E10	7 Nov	04:03:02.0	1.0	3091	43°01'N, 149°12'E	± 2
	E8	8 Nov	01:50:02.9	5.2	3018	44°00'N, 149°20'E	± 2
	E7	8 Nov	06:53:02.5	1.0	2288	44°23'N, 148°58'E	± 2
	E5	9 Nov	00:09:04.0	5.2	4454	44°31'N, 151°12'E	± 2
	E6	9 Nov	06:44:04:1	5.2	2660	43°31'N, 151°57'E	± 2
	E4	9 Nov	23:23:03.0	5.2	2393	45°35'N, 152°04'E	± 2
	E2	10 Nov	06:25:04.0	1.0	2215	46°20'N, 153°00'E	± 3
	E3	12 Nov	05:55:03.9	1.0	3130	46°07'N, 153°32'E	± 3
	E2A	12 Nov	23:31:03.0	5.2	1990	46°21'N, 152°58'E	± 2
	E1	13 Nov	05:48:03.0	5.2	1826	46°59'N, 153°54'E	± 2
Phase II	E12	2 Dec	22:30:02.8	5.2	2702	43°02'N, 150°25'E	± 2
	E13	3 Dec	05:21:02.9	5.2	4388	43°40'N, 149°42'E	± 2
	E7A	3 Dec	22:49:03.1	5.2	1417	44°25.5'N, 148°58'E	± 2
	E14	4 Dec	22:24:03.0	5.2	3945	44°35'N, 150°51'E	± 2
	E5A	5 Dec	03:22:03.1	1.5	4540	44°31'N, 151°22'E	± 2

*Celestial navigation was the primary means of navigation. Position accuracy was based on a best estimate from review of operations log book and data evaluation.

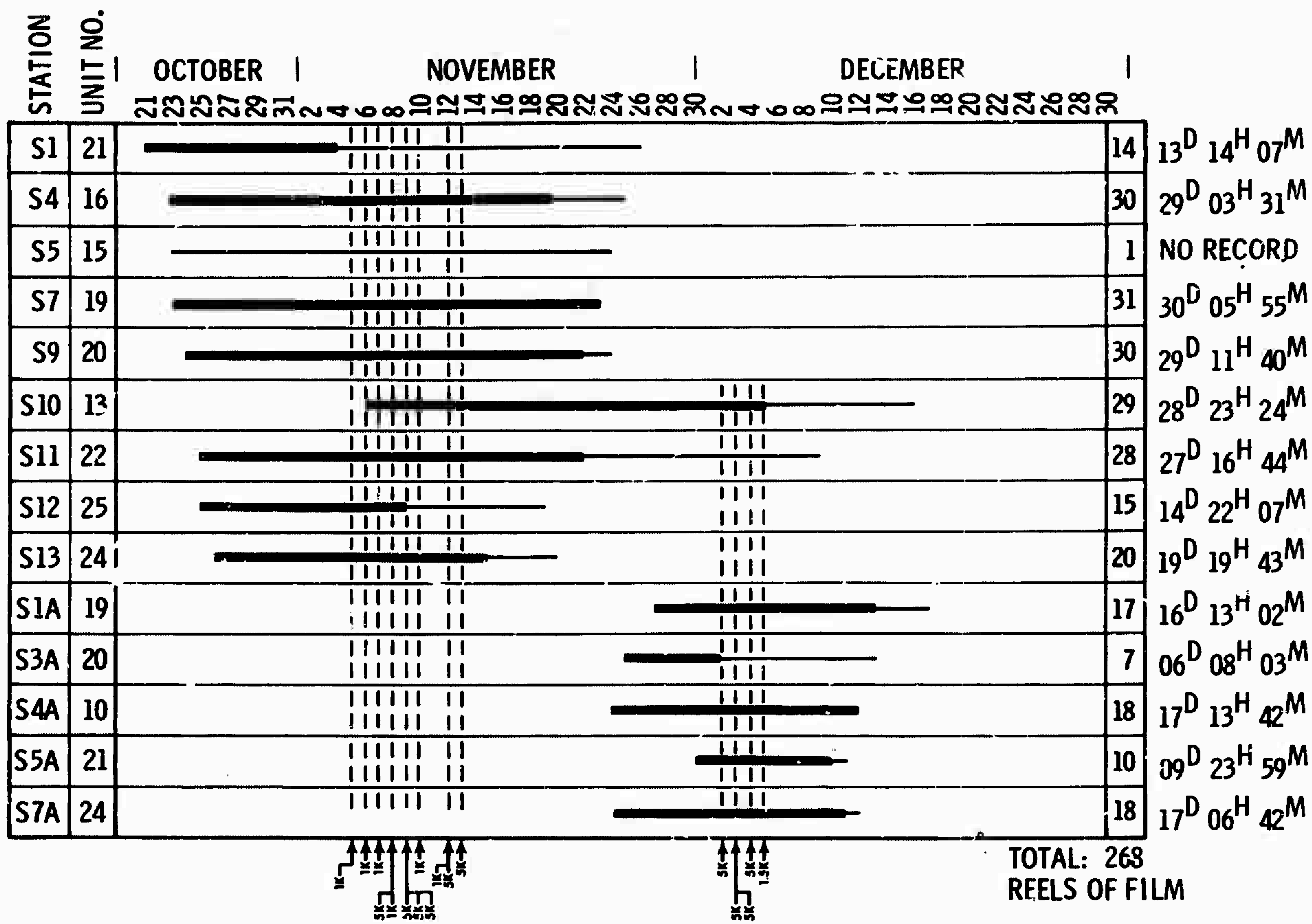


Figure II-1. Recording Periods, Kurile Islands Experiment

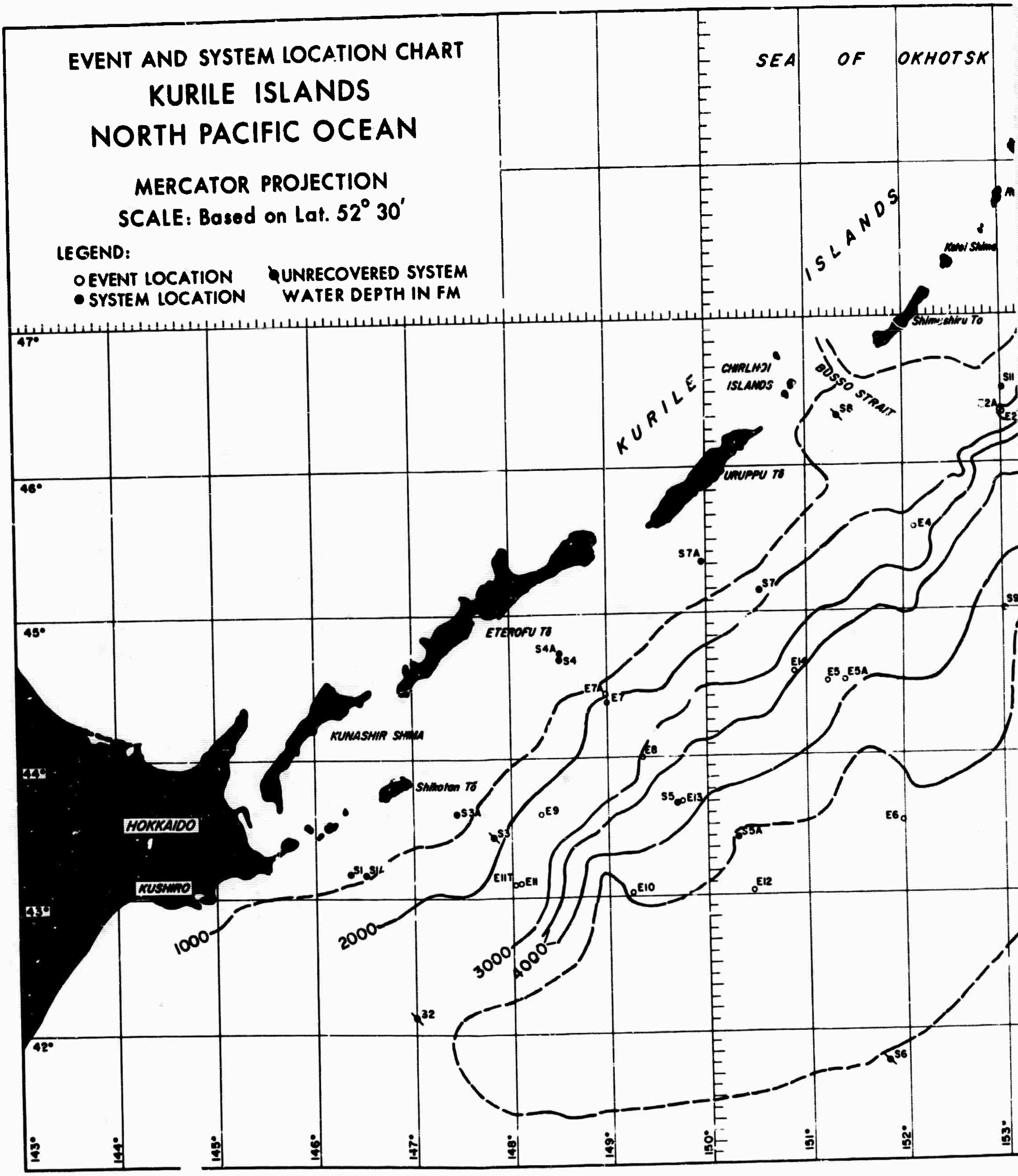


Figure II-2. Event and Sy

A

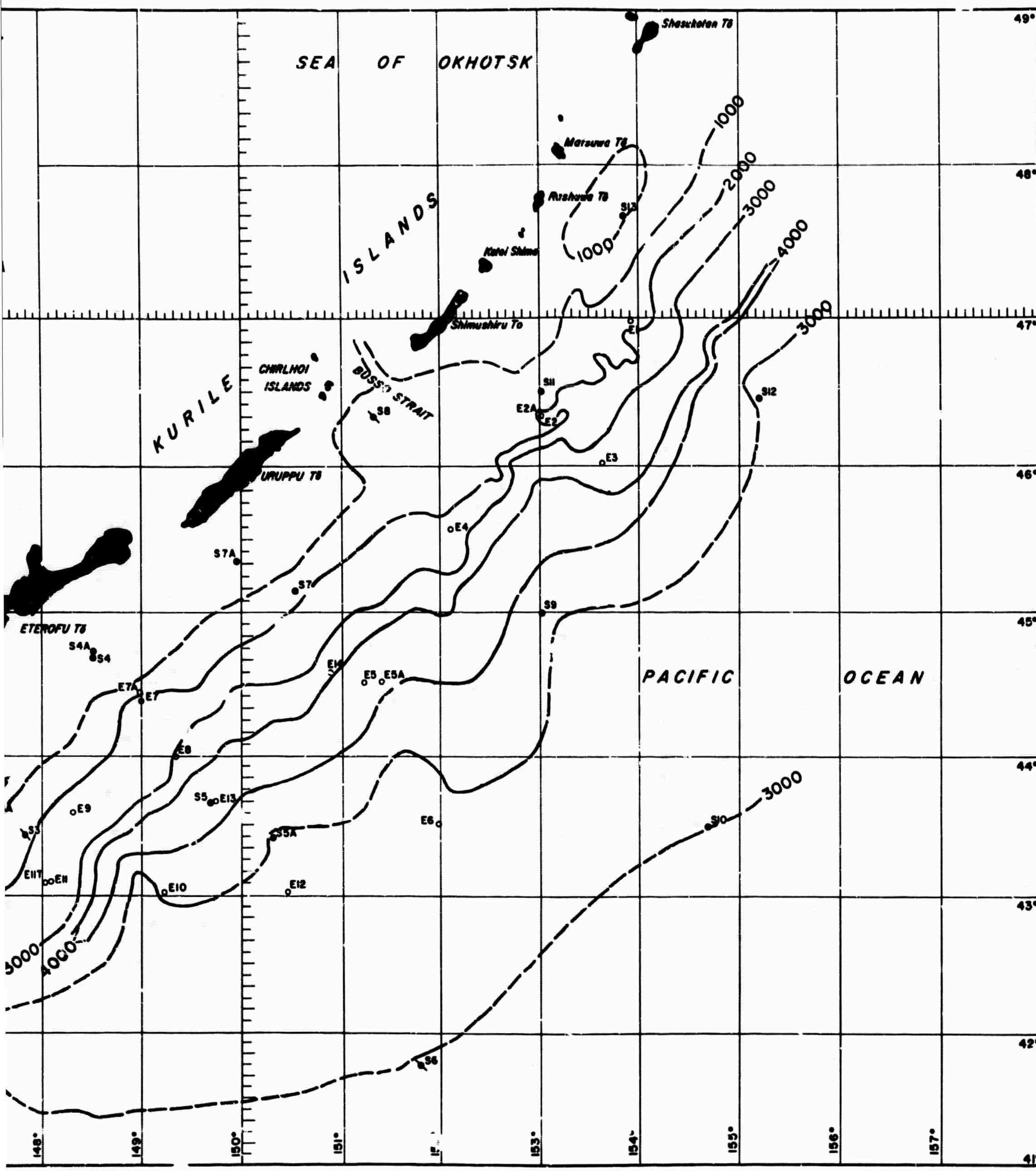


Figure II-2. Event and System Location Chart

SECTION III

PRELIMINARY DATA HANDLING

All data were transcribed from magnetic tape to 16-mm film. No frequency filtering was done, but the X10 and X100 channels were attenuated sufficiently to avoid trace overlapping. A total of 268 complete or partial days of recording was transcribed.

From the film, timing errors due to both misalignment of the recording heads and digital clock drift were determined. Head misalignment occurs either when the recording heads are skewed with respect to the direction of tape movement or when the two head banks (Figure III-1) are separated by an incorrect distance. The errors were determined from either amplifier "shutoff" pulses or daily instrument-calibration pulses and are referenced to the clock channel (channel 14). An example of head-alignment error is shown in Figure III-2.

Table III-1 lists the errors for each channel for each unit and shows that the errors were less than ±0.9 sec, except for the channels on recording head 2 of unit 10 (S4A). This head was separated from recording head 1 by an incorrect amount, causing a +7.2-sec error.

The station reset times (i.e., 0-time on the digital clock) were obtained by reading the WWV trace recorded on the pressure channel and then applying the appropriate correction needed to compensate for head misalignment. If the WWV trace could not be read, field logs were used to obtain the reset time.

Digital clock drifts were determined by comparing the total recording time indicated by the digital clock with the actual recording time (the difference between the WWV times recorded on the tape at reset and shutoff).

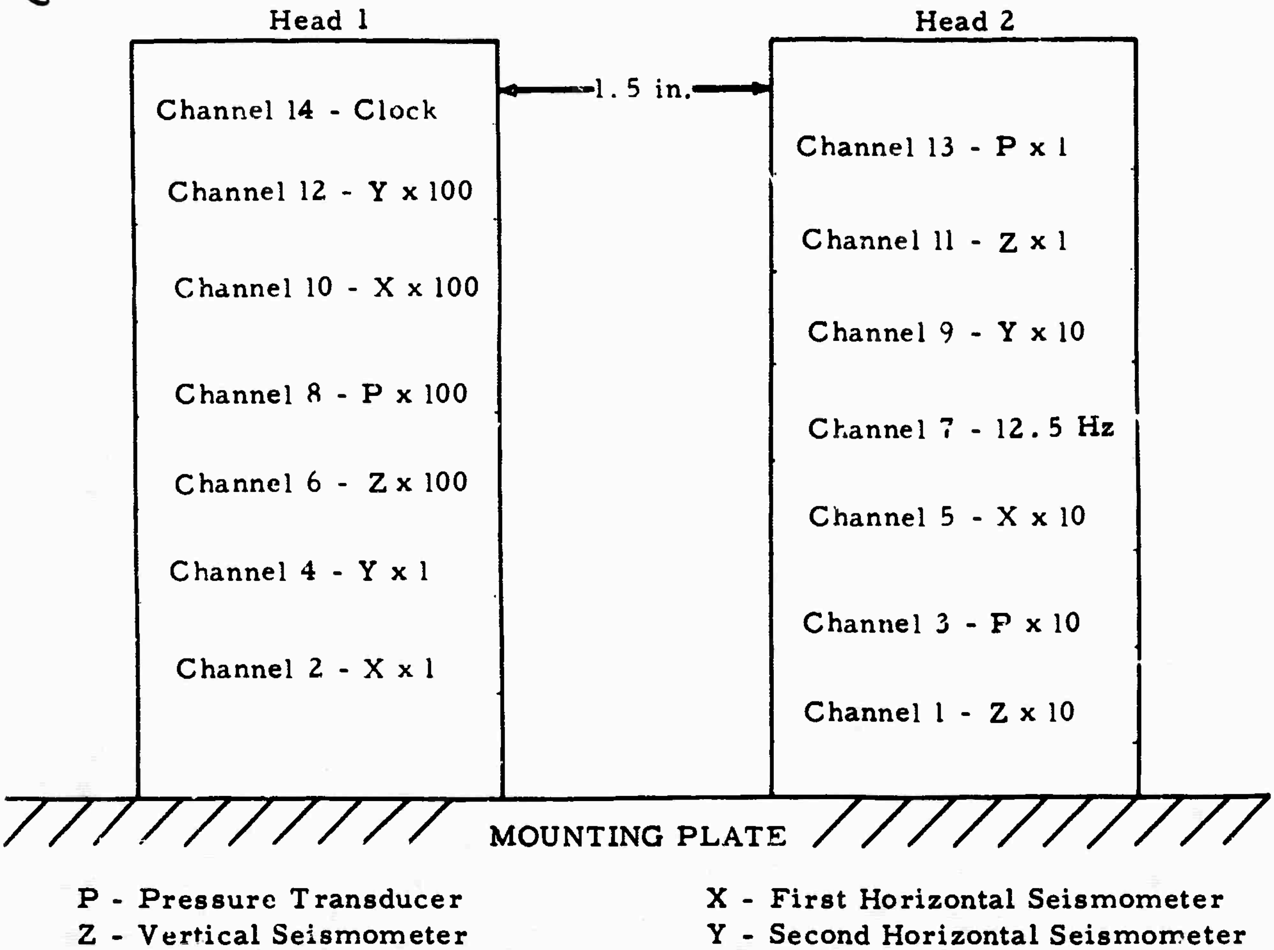


Figure III-1. Physical Channel Location on Top of Recording Heads on Tape Recorder

Figure III-2. Example of Timing Errors Due to Head Misalignment

Table III-1

CORRECTED UNIT-RESET TIMES AND CHANNEL-HEAD-ALIGNMENT ERRORS

Unit	Sta	Reset Time (GCT)	Corrected Reset Time (GCT)	Days Recorded	Clock Drift (sec)	Remarks	Channel Head-Alignment Errors (sec)											
							1	2	3	4	5	6	8	9	10	11	12	13
10	S4A	20:03:00.0	20:03:00.2	18	+0.2		+7.0	+0.2	+7.0	+0.2	+7.0	+0.2	+0.2	+7.2	0.0	+7.2	0.0	+7.2
13	S10	09:00:00.0	09:00:00.0	29	—	Excessive drain of battery power	-0.9	+0.4	-0.9	+0.3	-0.9	+0.2	+0.2	-0.9	0.0	-0.9	0.0	-0.9
15	S5	19:43:00.0	19:43:00.7	0	—	Tape did not pull	-0.3	0.0	-0.3	0.0	-0.4	+0.1	+0.1	-0.4	0.0	-0.5	0.0	-0.5
16	S4	11:00:00.0	10:59:59.9	30	—	Repetitious clock code	0.0	+0.1	0.0	+0.2	+0.1	0.0	0.0	-0.2	0.0	-0.3	0.0	-0.3
19	S7	22:07:00.0	22:07:03.2	31	-5.3		-0.2	0.0	-0.2	0.0	-0.2	0.0	0.0	-0.2	0.0	-0.3	0.0	-0.2
19	S1A	00:43:00.0	00:43:00.0	17	0.0		-0.2	-0.1	-0.2	0.0	-0.2	0.0	0.0	-0.2	0.0	-0.2	0.0	-0.2
20	S9	10:06:00.0	10:06:00.5	30	-0.1		0.0	+0.2	0.0	+0.3	-0.1	+0.2	0.0	-0.2	0.0	-0.2	0.0	-0.3
20	S3A	21:03:00.0	21:02:59.1	7	-3.0		0.0	+0.2	0.0	+0.1	-0.1	+0.2	+0.1	-0.2	0.0	-0.3	0.0	-0.3
21	S1	16:57:00.0	16:56:59.6	14	+0.7		0.0	+0.4	+0.1	+0.4	0.0	+0.3	+0.1	0.0	0.0	0.0	0.0	0.0
21	S5A	02:05:00.0	02:05:00.1	10	+0.9		0.0	+0.3	0.0	+0.2	0.0	+0.1	+0.1	0.0	0.0	0.0	0.0	-0.1
22	S11	08:44:00.0	08:44:00.5	28	+0.3		+0.3	+0.2	+0.2	+0.2	0.0	+0.1	+0.1	-0.1	0.0	-0.2	0.0	-0.3
24	S13	09:49:00.0	09:49:00.4	20	-1.1		+0.3	-0.5	+0.3	0.0	+0.1	0.0	0.0	+1.5	-0.1	+0.2	0.0	+0.1
24	S7A	03:02:00.0	03:02:00.2	18	+0.3		+0.2	-0.1	+0.1	-0.1	+0.2	0.0	0.0	+0.1	0.0	+0.1	0.0	+0.1
25	S12	21:43:00.0	21:43:00.2	15	+0.7		-0.1	+0.1	0.0	+0.1	-0.1	+0.1	+0.2	-0.1	0.0	-0.1	0.0	-0.1

Table III-1 lists the clock drifts for all units except 13 (S10A) and 16 (S4) for which drifts could not be obtained. Drifts were small except for units 19 (S7) and 20 (S3A), which had -5.3-sec and -3.0-sec errors, respectively. Corrections for clock drifts were made, assuming that the drift was linear over the recording period.

WWV times were obtained by adding the corrected reset time to the digital clock times and subtracting the appropriate clock drift and channel-head-alignment errors. The errors given in Table III-1 were applied in preparing the Preliminary Bulletin.

SECTION IV

DATA ANALYSIS

A. PREPARATION OF PRELIMINARY BULLETIN

The first task in the data analysis was to prepare a preliminary bulletin reporting all arrivals observed during the recording period. Details of the bulletin preparation are presented in the Preliminary Bulletin.[4] A total of 3188 station events was observed: 320 were associated with 89 USC&GS preliminary epicenters, 87 were associated with the 17 explosions, 364 were used to locate 70 preliminary epicenters from OBS data alone, 741 were associated with 200 assumed events for which epicentral locations were not obtained either due to insufficient data or due to divergence while attempting to determine the epicenter, and 1676 were classed as unassociated events.

B. VELOCITY STUDY

To determine P-wave velocities in the Kurile region, data from the 17 explosions and from 13 local earthquakes with focal depth of 33 km were analyzed.

For the explosion data, an attempt was made to construct several profiles which were either parallel or perpendicular to the Kurile trench, but available data were insufficient. Consequently, all the explosion data were used to determine average crustal and mantle P-wave velocities in the region.

Table IV-1 lists the explosions and the units at which arrivals were picked. Arrivals generally could be picked to within ±1.0 sec; but some arrivals had emergent onsets, and larger errors in these arrival times are likely. After a preliminary scanning of the data, traveltimes were corrected as follows.

- It was assumed that there was a uniform 2.0-km layer of unconsolidated sediments over the whole region. This assumption was based on the work of Kosminskaya et al,[5] who gave a contour map of the depth to the top of the consolidated sediments and indicated that in the South Kurile region the contours agreed grossly with the bottom topography. Also, assuming a uniform thickness makes it unnecessary to know the velocity structure in the unconsolidated sediments (which is not well-known), as the traveltimes in the unconsolidated layer would be essentially the same at each station.

- For units less than 1.0° from the shot, first arrivals were assumed to be refracted along the top of the consolidated crust. Thus, the traveltime in water beneath the shotpoint was computed (using a velocity of 1.5 km/sec) and subtracted from the observed traveltime to remove variations in water depth.

- For units between 1.0° and 6.1° from the shot, first arrivals were assumed to be refracted along deeper interfaces. A datum plane of 8.4 km below sea level (i.e., the deepest water depth) was chosen, and the traveltimes in the water beneath the shot and in the consolidated sediments beneath both the shot and seismometer were computed and subtracted from the observed traveltimes. The vertical depth rather than the true-refraction path was used to correct the traveltime in water. However, the error resulting from this simplification is small. Using normal techniques for refraction corrections, errors would be no more than 0.3 sec.

- Beyond 6.1°, first arrivals appeared to have propagated in the upper mantle and were not considered.

Table IV-1

CORRECTED TRAVELTIMES FOR THE EXPLOSION DATA

Explosion	Unit	Δ	Explosion Water Corr. (sec)	Explosion Crustal Corr. (sec)	Unit Crustal Corr. (sec)	Total Corr. (sec)	Traveltime Observed (sec)	Corrected Traveltime (sec)
E7	S4	0.5	2.8	0.0	0.0	2.8	14.1	11.3
	S7	1.3	2.8	0.4	0.6	3.8	27.9	24.1
	S9	2.9	2.8	0.4	0.1	3.3	48.3	45.0
	S11	3.5	2.8	0.4	0.5	3.7	57.4	53.7
	S10	4.1	2.8	0.4	0.1	3.3	68.6	65.3
	S12	4.8	2.8	0.4	0.2	3.4	72.5	69.1
E5	S7	0.8	5.4	0.0	0.0	5.4	21.2	15.8
	S9	1.4	5.4	0.0	0.1	5.5	27.3	21.8
	S4	1.9	5.4	0.0	1.0	6.4	36.8	30.4
	S11	2.4	5.4	0.0	0.5	5.9	40.9	35.0
	S10	2.6	5.4	0.0	0.1	5.5	43.6	38.1
	S12	3.4	5.4	0.0	0.2	5.6	54.0	48.4
	S13	3.7	5.4	0.0	0.6	6.0	59.0	53.0
E6	S9	1.7	3.2	0.2	0.0	3.4	27.0	23.6
	S7	1.9	3.2	0.2	0.6	4.0	32.2	28.2
	S10	2.0	3.2	0.2	0.1	3.5	33.6	30.1
	S4	2.7	3.2	0.2	1.0	4.4	40.0	35.6
	S11	3.1	3.2	0.2	0.5	3.9	46.2	42.3
	S12	3.8	3.2	0.2	0.2	3.6	55.0	51.4
	S13	4.4	3.2	0.2	0.6	4.0	67.9	63.9
E4	S9	0.9	2.9	0.0	0.0	2.9	19.2	16.3
	S11	1.1	2.9	0.3	0.5	3.7	20.7	17.0
	S7	1.2	2.9	0.3	0.6	3.8	25.3	21.5
	S13	2.4	2.9	0.3	0.6	3.8	38.9	35.1
	S4	2.7	2.9	0.3	1.0	4.2	46.1	41.9
E2	S11	0.2	2.7	0.0	0.0	2.7	3.5	0.8
	S9	1.3	2.7	0.4	0.1	3.2	24.7	21.5
	S13	1.5	2.7	0.4	0.6	3.7	22.7	19.0
	S7	2.1	2.7	0.4	0.6	3.7	34.7	31.0
E7A	S4A	0.5	1.7	0.0	0.0	1.7	12.1	10.4
	S5A	1.4	1.7	0.6	0.1	2.4	27.4	25.0
	S10	4.1	1.7	0.6	0.1	2.4	65.9	63.5
E14	S5A	1.3	4.8	0.0	0.1	4.9	25.3	20.4
	S10	2.8	4.8	0.0	0.1	4.9	44.9	40.0
	S1A	3.5	4.8	0.0	0.8	5.6	55.0	49.4
E5A	S7A	1.3	5.5	0.0	0.9	6.4	29.6	23.2
	S5A	1.4	5.5	0.0	0.0	5.5	24.2	18.7
	S1A	3.8	5.5	0.0	0.8	6.3	63.9	57.6

Explo-sion	Unit	Δ	Explosion Water Corr. (sec)	Explosion Crustal Corr. (sec)	Unit Crustal Corr. (sec)	Total Corr. (sec)	Traveltime Observed (sec)	Corrected Traveltime (sec)
	S11	0.5	3.8	0.0	0.0	3.8	11.8	8.0
	S9	1.2	3.8	0.1	0.1	4.0	23.0	19.0
	S13	1.6	3.8	0.1	0.6	4.5	32.0	27.5
	S7	2.3	3.8	0.1	0.6	4.5	45.2	40.7
E2A	S11	0.2	2.4	0.0	0.0	2.4	5.3	2.9
	S9	1.3	2.4	0.4	0.1	2.9	24.9	22.0
	S13	1.5	2.4	0.4	0.6	3.4	24.3	20.9
	S7	2.1	2.4	0.4	0.6	3.4	35.7	32.3
	S10	2.9	2.4	0.4	0.1	2.9	46.0	43.1
	S4	3.6	2.4	0.4	1.0	3.8	54.6	50.8
E1	S13	0.7	2.2	0.0	0.0	2.2	12.9	10.7
	S11	0.8	2.2	0.0	0.0	2.2	15.6	13.4
	S9	2.1	2.2	0.5	0.1	2.8	34.7	31.9
	S7	3.0	2.2	0.5	0.6	3.3	39.6	36.3
E12	S5A	0.4	3.3	0.0	0.0	3.3	10.6	7.3
	S1A	2.9	3.3	0.2	0.8	4.3	48.0	43.7
	S10	3.1	3.3	0.2	0.1	3.6	43.3	39.7
E13	S4A	1.3	5.3	0.0	1.0	6.3	29.2	22.9
	S7A	1.7	5.3	0.0	0.9	6.2	33.5	27.3
	S1A	2.4	5.3	0.0	0.8	6.1	43.9	37.8
	S10	3.5	5.3	0.0	0.1	5.4	60.4	55.0
E11	S7	2.7	2.7	0.4	0.6	3.7	45.2	41.5
	S9	4.0	2.7	0.4	0.1	3.2	62.2	59.0
	S11	4.9	2.7	0.4	0.5	3.[illegible]	74.7	71.1
	S12	6.1	2.7	0.4	0.2	3.3	89.5	86.2
E9	S4	1.1	2.8	0.3	1.0	4.1	22.9	18.8
	S7	2.2	2.8	0.3	0.6	3.7	38.7	35.0
	S9	3.7	2.8	0.3	0.1	3.2	56.8	53.6
E10	S4	1.8	3.8	0.1	1.0	4.9	33.1	28.2
	S7	2.3	3.8	0.1	0.6	4.5	39.1	34.6
	S9	3.4	3.8	0.0	0.0	3.8	52.7	48.9
	S11	4.4	3.8	0.1	0.5	4.4	67.4	63.0
	S12	5.5	3.8	0.1	0.2	4.1	81.1	77.0
	S13	5.7	3.8	0.1	0.6	4.5	85.2	80.8
E8	S4	0.9	3.7	0.0	0.0	3.7	22.0	18.3
	S7	1.4	3.7	0.1	0.6	4.4	29.3	24.9
	S9	2.8	3.7	0.1	0.1	3.9	47.1	43.2
	S11	3.6	3.7	0.1	0.5	4.3	58.7	54.4
	S10	3.8	3.7	0.1	0.1	3.9	61.4	57.5
	S12	4.8	3.7	0.1	0.2	4.0	74.3	70.3

Figures IV-1 and IV-2 show least-squares fits of the two sets of data and give P-wave velocities of 5.4 km/sec for the consolidated crust and 8.1 km/sec for the mantle. No intermediate layers appear to be defined by the first-arrival data. The data in both figures show substantial scatter (the standard deviations are 1.5 and 2.5 sec, respectively), which should be expected because of the emergent nature of some arrivals and because no corrections have been made for dipping interfaces or variations in the thickness of unconsolidated sediments. However, results are consistent with average velocities found by Kosminskaya and with those from the earthquake data.

The intercept times are -1.5 sec for Figure IV-1 and 3.3 sec for Figure IV-2. Ideally, the intercept for Figure IV-1 would be 0.0 sec; the error is about one standard deviation, which is essentially the accuracy of the data. The standard deviation for Figure IV-2 is almost as large as the intercept time. However, the 3.3-sec intercept yields a depth to the Moho discontinuity of about 18 km, which is reasonable for combined ridge and oceanic data.

Table IV-2 lists the earthquakes used in the analysis. The events were divided into two groups: those to the south of the region and those to the north. Two events which occurred in the northern end of the network were included with the northern earthquakes. Only arrivals at the seismometers on the island side of the trench were plotted in Figures IV-3 and IV-4 so that an approximate reverse profile could be obtained. The seismometers on the ocean side of the trench were not included because of their large offset from the refraction line and because arrivals would have to cross the trench structure diagonally, which could cause large time-residuals.

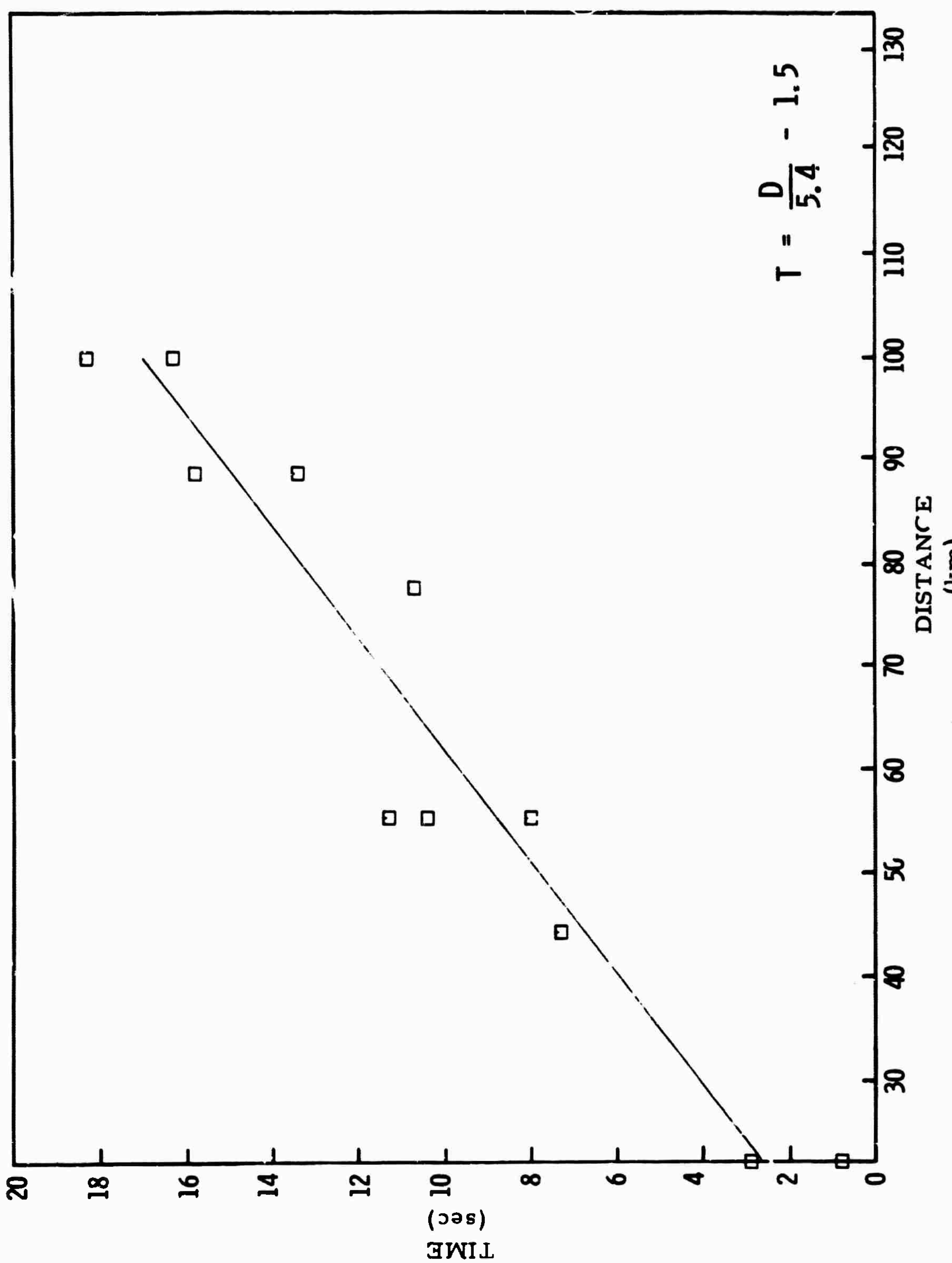


Figure IV-1. Time-Distance Plot, Events Less Than 1.0° Epicentral Distance, Explosion Data

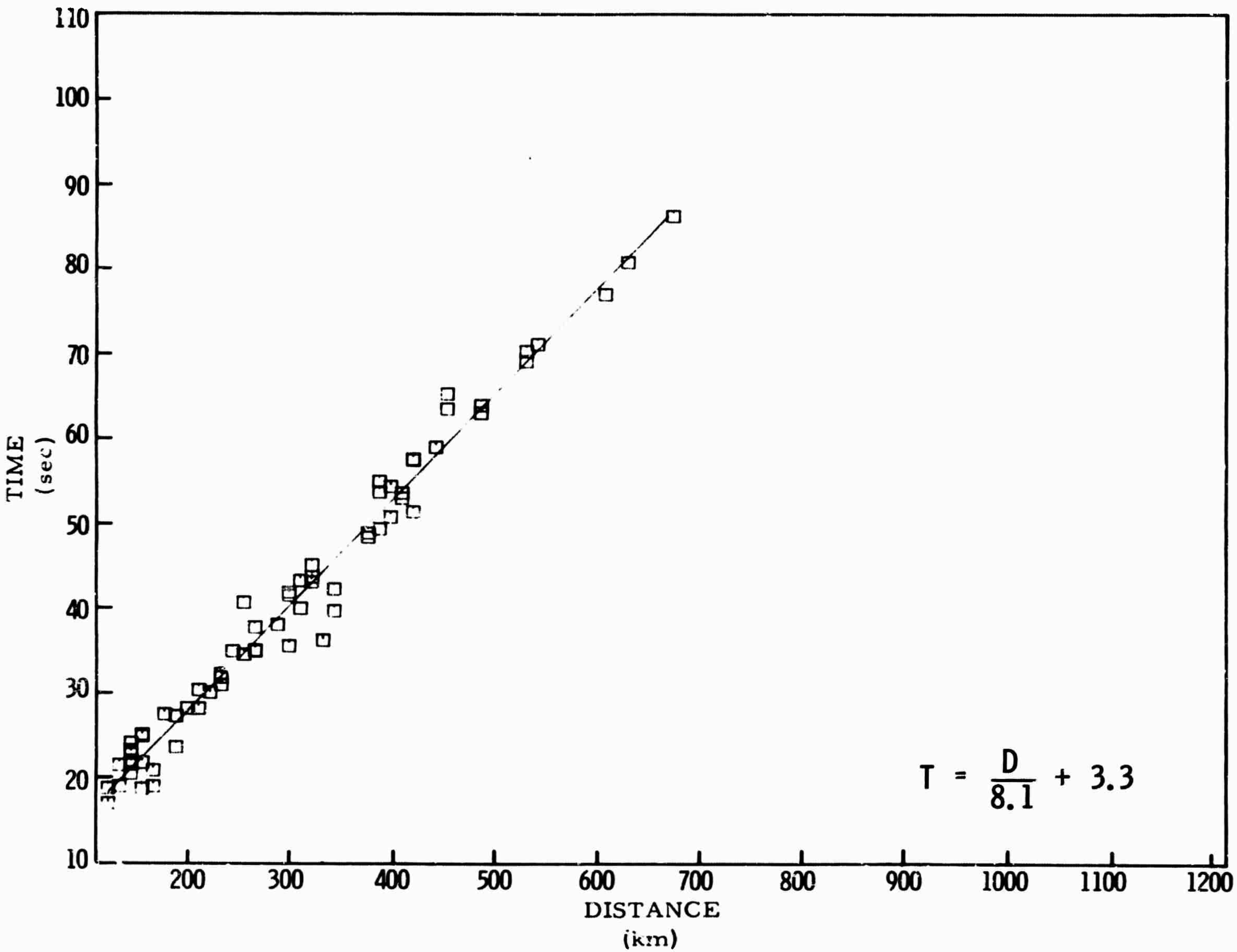


Figure IV-2. Time-Distance Plot, Events Between 1.0° and 6.1° Epicentral Distance, Explosion Data

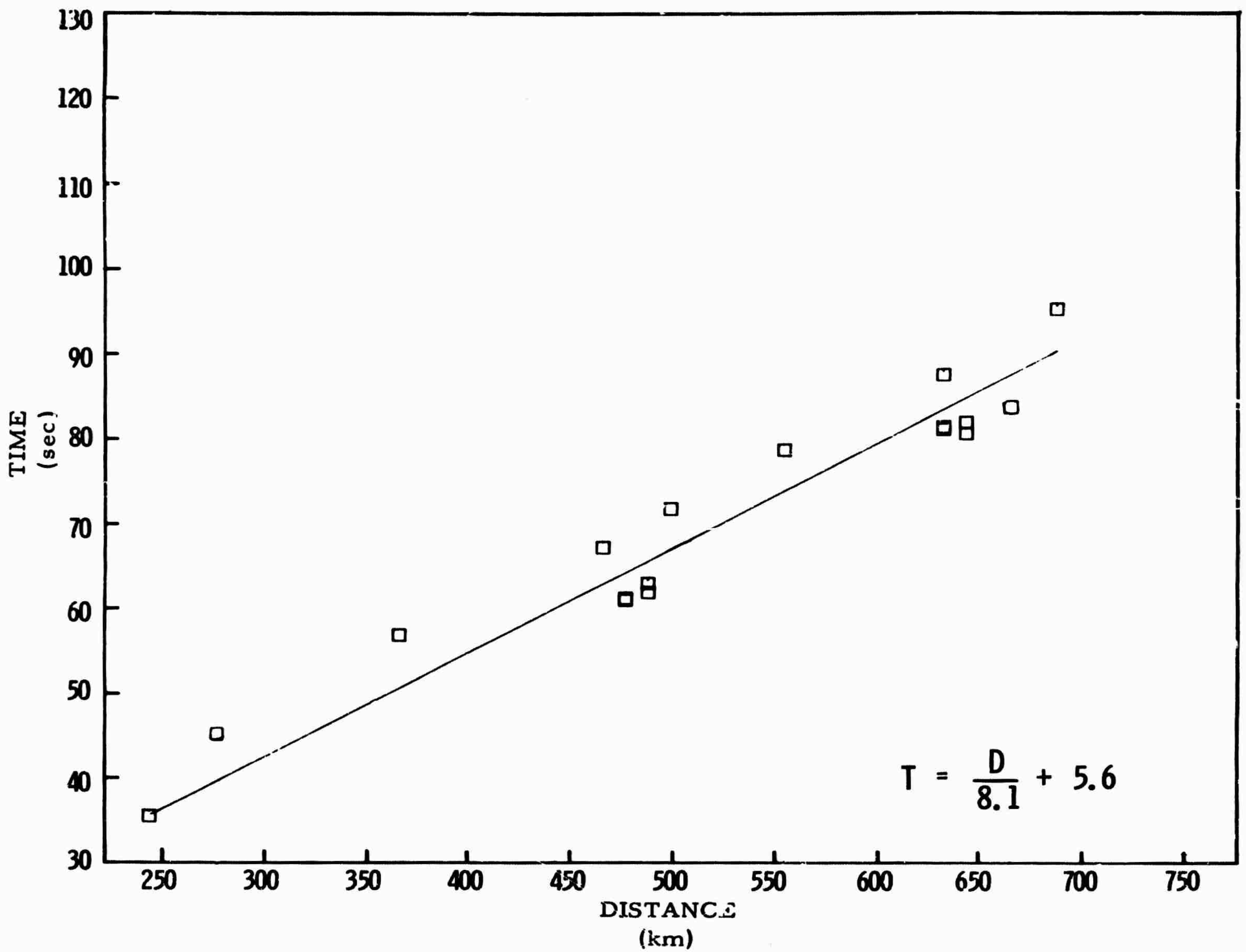


Figure IV-3. Time-Distance Plot, Southern Profile, Earthquake Data

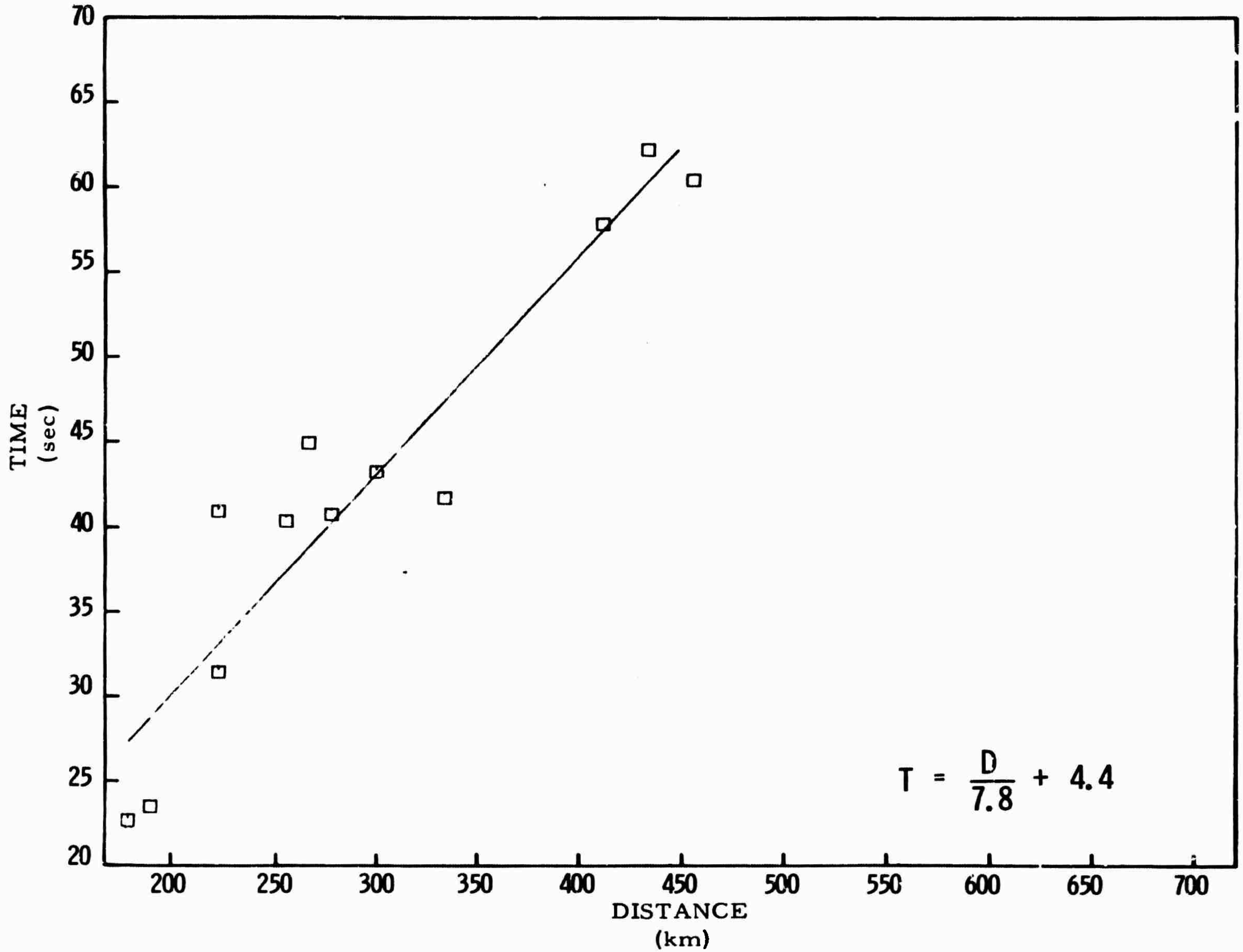


Figure IV-4. Time-Distance Plot, Northern Profile, Earthquake Data

Table IV-2

TRAVELTIMES FOR THE EARTHQUAKE DATA

Area	Date (1966)	Time on Unit	Location Lat.	Location Long.	Mag.	Depth (km)	Δ (°)	Travel-time (sec)	Unit	Origin Time	
Kamchatka	10/29	00:46:48.7	51.1°N	159.1°E	4.3	33	4.9	68.7	S13	00:45:40.0	NORTHERN PROFILE
		00:46:53.5					5.3	73.5	S12		
		00:47:06.2					6.1	86.2	S11		
		00:47:21.6					7.3	101.6	S9		
		00:47:33.1					8.3	113.1	S7		
Kurile Is.	11/6	03:50:21.8	45.7°N	151.0°E	4.5	33	.7	10.8	S7	03:50:11.0	
		03:50:33.7					1.6	22.7	S11		
		03:50:42.4					2.0	31.4	S4		
		03:50:51.9					2.8	40.9	S13		
		03:50:49.3					3.0	38.3	S12		
Kurile Is.	11/12	17:34:13.4	45.1°N	151.7°E	4.8	33	.8	21.4	S7	17:33:52.0	
		17:34:08.3					.9	16.3	S9		
		[illegible] 15.5					1.7	23.5	S11		
		1[illegible]:32.3					2.3	40.3	S4		
		17:34:32.1					2.5	40.1	S10		
		17:34:33.7					3.0	41.7	S13		
Kurile Is.	11/12	20:44:10.0	46.6°N	153.7°E	4.8	33	.5	8.7	S11	20:44:01.3	
		20:44:24.8					1.7	23.5	S9		
		20:44:44.5					2.7	43.2	S7		
		20:44:42.2					3.0	40.9	S10		
		20:45:01.7					4.1	60.4	S4		
Kurile Is.	11/12	19:27:15.8	46.2°N	153.6°E	4.4	33	.5	10.8	S11	19:27:05.0	
		19:27:30.6					1.3	25.6	S9		
		19:27:47.9					2.7	42.9	S10		
		19:27:49.9					2.4	44.9	S7		
		19:28:07.2					3.9	62.2	S4		
Kurile Is.	11/30	00:05:16.7	46.9°N	152.7°E	4.4	33	2.5	40.7	S7A	00:04:36.0	
		00:05:25.1					3.5	49.1	S10		
		00:05:33.8					3.7	57.8	S4A		
		00:05:52.9					5.0	76.9	S3A		
		00:06:02.5					5.0	86.5	S1A		
Hokkaido	10/29	06:30:57.5	41.8°N	144.0°E	4.7	32	2.2	35.5	S1	06:30:22.0	SOUTHERN PROFILE
		06:31:24.9					4.4	62.9	S4		
		06:31:42.6					5.8	80.6	S7		
		06:32:03.0					7.3	101.0	S9		
		06:32:12.2					8.0	110.2	S11		
		06:32:28.3					9.1	126.3	S13		
		06:32:28.4					9.3	126.4	S12		
Hokkaido	11/12	12:50:44.6	41.8°N	144.1°E	5.8	33	4.3	61.0	S4	12:49:43.6	
		12:51:04.7					5.7	81.1	S7		
		12:51:23.2					7.2	99.6	S9		
		12:51:32.9					7.9	110.7	S11		
		12:51:32.8					7.9	110.6	S10		
		12:51:49.5					9.1	125.9	S13		
Hokkaido	11/12	17:16:54.9	41.5°N	144.3°E	4.6	33	4.4	61.9	S4	17:15:53.0	
		17:17:14.9					5.8	81.9	S7		
		17:17:33.6					7.3	100.6	S9		
		17:17:44.7					7.9	111.7	S10		
		17:17:42.7					8.0	109.7	S11		
Hokkaido	11/12	23:06:00.0	41.7°N	144.2°E	4.7	33	4.3	61.2	S4	23:04:58.8	
		23:06:20.2					5.7	81.4	S7		
		23:06:39.0					7.2	100.2	S9		
		23:06:48.1					7.9	109.3	S10		
		23:06:49.2					7.9	109.6	S11		
		23:07:05.2					9.1	126.4	S13		
Hokkaido	11/29	14:09:00.0	42.2°N	143.4°E	4.1	33	3.3	46.2	S1A	14:08:13.8	
		14:09:10.7					3.3	56.9	S3A		
		14:09:25.6					4.5	71.8	S4A		
		14:09:41.3					5.7	87.5	S7A		
		14:10:16.3					8.3	122.5	S10		
Honshu	11/19	07:32:38.1	40.5°N	142.7°E	4.3	33	6.0	84.1	S4	07:31:14.0	
		07:32:59.4					7.4	105.4	S7		
		07:33:14.8					8.8	120.8	S9		
		07:33:23.1					9.4	129.1	S10		
		07:33:25.[illegible]					9.6	131.9	S11		
Honshu	12/1	15:22:10.8	40.7°N	142.0°E	3.9	33	4.2	67.2	S1A	15:21:03.6	
		15:22:22.3					5.0	78.7	S3A		
		15:22:38.8					6.2	95.2	S4A		
		15:23:27.2					9.8	143.6	S10		

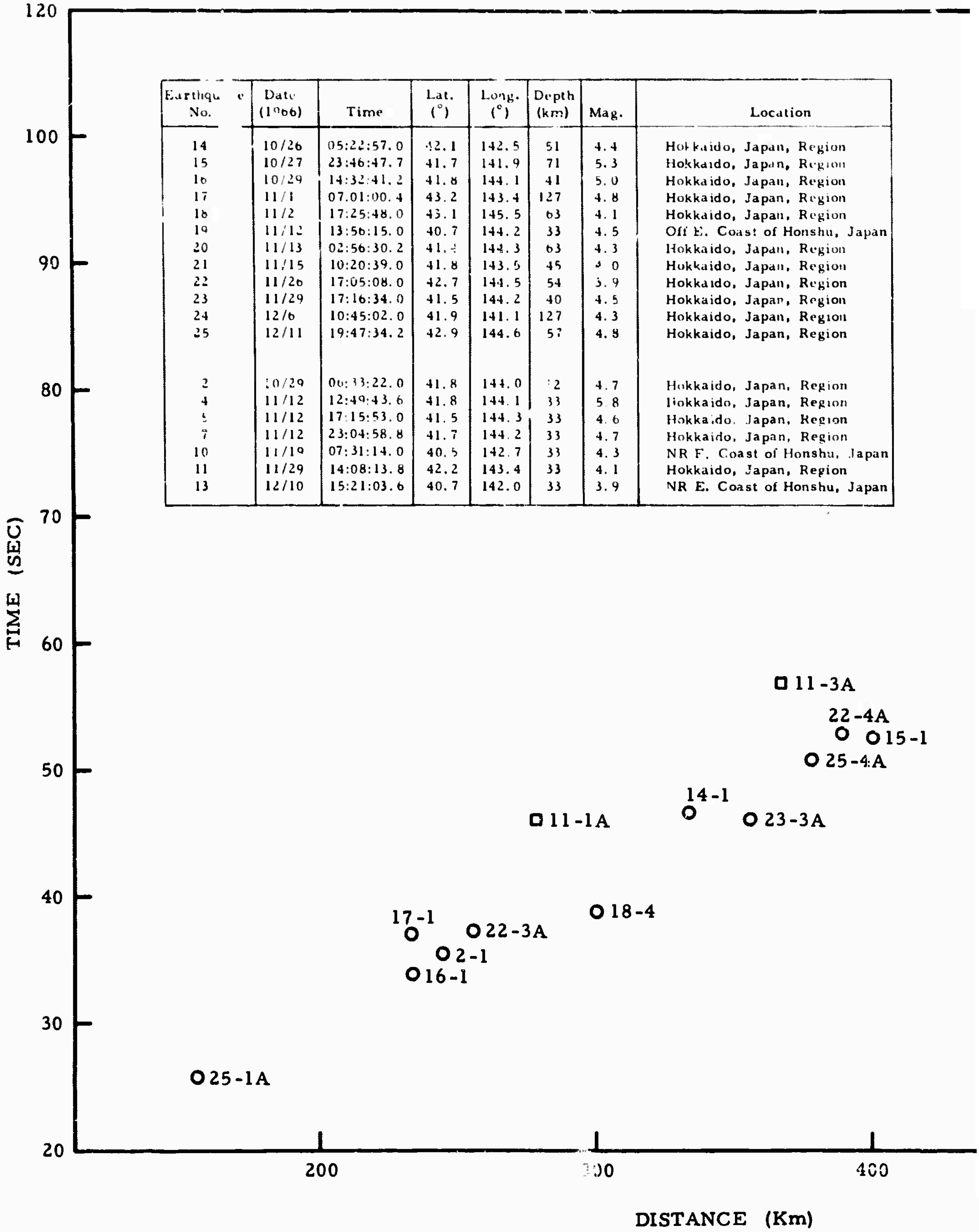
In all cases, first arrivals were well-defined and could be picked to within ±1.0 sec. A datum of 3.0 km below sea level (depth of S-11, the deepest island-side seismometer) was chosen, and crustal corrections were computed as above. However, all corrections were less than 0.65 sec, so the data were plotted without adjustment; i.e., the maximum correction would be for the shallowest seismometers (S4 and S4A), which are 1420 fm (2.6 km) above the datum. Using a crustal velocity of 5.4 km/sec and a Moho velocity of 8.1 km/sec:

$$T = \frac{2.6}{\cos\left(\arc \sin \frac{5.4}{8.1}\right)} \Bigg/ 5.4 = 0.65 \text{ sec}$$

Thus, the corrections are small with respect to cumulative errors of timing and those associated with earthquake locations.

Figures IV-3 and IV-4 show least-squares fits to the southern and northern profiles, respectively. No intermediate refractors are indicated.

In Figure IV-3, the traveltime points from earthquakes 11 and 13 fall above the straight-line fits, while those from earthquakes 2, 4, 5, 7, and 10 are below straight-line fit. A time-intercept difference of about 8 sec is observed when the two sets of timepoints are fitted independently. Since stations S4 and S4A occupy essentially the same location and the time anomaly for the two sets of earthquakes is observed at this location, it appears that the anomaly must be associated with the sources. Consequently, arrival times from several additional earthquakes which occurred in the same region but at depths between 41 and 127 km were plotted (Figure IV-5). All points form groups with the earthquakes below the line. Thus, it appears that one of the parameters (epicenter, depth, or origin time) associated with earthquakes 11 and 13 is in error. An erroneous epicentral location appears to be most likely, since an error of 50 to 75 km (which is about the accuracy quoted by the USC&GS) would give the observed delay.



Earthquake No.	Date (1966)	Time	Lat. (°)	Long. (°)	Depth (km)	Mag.	Location
14	10/26	05:22:57.0	42.1	142.5	51	4.4	Hokkaido, Japan, Region
15	10/27	23:46:47.7	41.7	141.9	71	5.3	Hokkaido, Japan, Region
16	10/29	14:32:41.2	41.8	144.1	41	5.0	Hokkaido, Japan, Region
17	11/1	07.01:00.4	43.2	143.4	127	4.8	Hokkaido, Japan, Region
18	11/2	17:25:48.0	43.1	145.5	63	4.1	Hokkaido, Japan, Region
19	11/12	13:56:15.0	40.7	144.2	33	4.5	Off E. Coast of Honshu, Japan
20	11/13	02:56:30.2	41.4	144.3	63	4.3	Hokkaido, Japan, Region
21	11/15	10:20:39.0	41.8	143.5	45	[illegible]	Hokkaido, Japan, Region
22	11/26	17:05:08.0	42.7	144.5	54	3.9	Hokkaido, Japan, Region
23	11/29	17:16:34.0	41.5	144.2	40	4.5	Hokkaido, Japan, Region
24	12/6	10:45:02.0	41.9	141.1	127	4.3	Hokkaido, Japan, Region
25	12/11	19:47:34.2	42.9	144.6	57	4.8	Hokkaido, Japan, Region
2	10/29	06:33:22.0	41.8	144.0	[illegible]	4.7	Hokkaido, Japan, Region
4	11/12	12:49:43.6	41.8	144.1	33	5.8	Hokkaido, Japan, Region
5	11/12	17:15:53.0	41.5	144.3	33	4.6	Hokkaido, Japan, Region
7	11/12	23:04:58.8	41.7	144.2	33	4.7	Hokkaido, Japan, Region
10	11/19	07:31:14.0	40.5	142.7	33	4.3	NR F. Coast of Honshu, Japan
11	11/29	14:08:13.8	42.2	143.4	33	4.1	Hokkaido, Japan, Region
13	12/10	15:21:03.6	40.7	142.0	33	3.9	NR E. Coast of Honshu, Japan

A

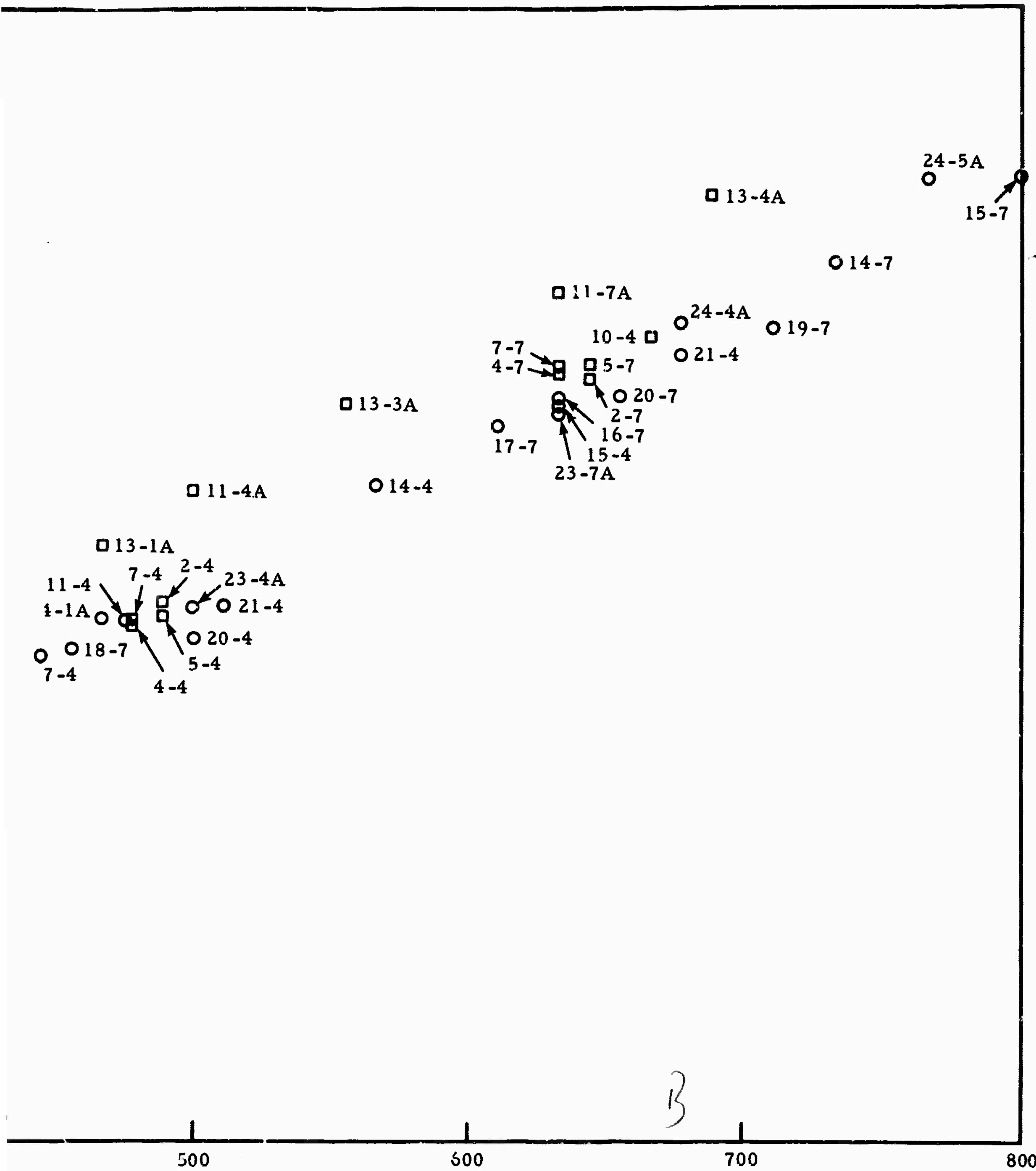


Figure IV-5. Time-Distance Plot Showing Southern-Profile Earthquakes and Deeper-Focus Earthquakes from the Same Region

BLANK PAGE

A least-squares fit was not done for Figure IV-5, because the earthquake depths are such that the travel paths would be in the upper mantle rather than along the Moho. Also, the 86-km depth range is large enough that the arrivals would have different travel paths.

The least-squares fit shown in Figure IV-3 was recomputed, excluding the data from earthquakes 11 and 13. The resulting traveltime equation was

$$T = \frac{\Delta}{8.3} + 5.6$$

The standard deviation was 0.9 sec, however, it should be noted that only nine points were used for the line fit. In Figure IV-4, considerable scatter can be seen. Also, arrivals from more than 4.5° away appear to have propagated in the upper mantle and, therefore, are excluded. The least-squares fit gave a velocity of 7.8 km/sec, an intercept of 4.4 sec, and a standard deviation of 4.1 sec. Combining the northern and southern velocities gives a Moho velocity of 8.1 km/sec, which is the same as that obtained from the explosion data. Using the 5.6-sec intercept time for the southern profile, a layer over half-space model, and adjusting for the fact the ray-paths have only one crustal leg, a Moho depth of approximately 41 km in the area of the stations was found. This depth estimate is considerably higher than founded for the explosion data, and is probably less reliable because of the uncertainties associated with the earthquake hypocenters (especially depth). Because of the large standard deviation for the northern profile, no depth calculation was made.

The "normal" upper-mantle velocity obtained from both explosion and earthquake data suggests that, unless an unusual velocity structure existed below the Moho, no severe traveltime anomalies would be obtained for earthquakes from the southern Kurile region

C. NOISE STUDY

Standard visual techniques were used to reduce the noise data. The maximum zero-to-peak noise amplitude (in millimeters) during the first minute after each GCT hour was read on the S10 vertical channel for each unit.

When an event occurred in the first minute after a GCT hour, the second or third minute was used to obtain the noise measurement. The corresponding half-period (to the nearest 0.1 sec) was obtained also, and the reading was converted to ground motion in millimicrons using the OBS system amplitude response.

Preliminary analysis showed that changes in noise amplitude were gradual, so readings were plotted only every 6 hr. Also, because of the rapid variation in system response over the period range (0.6 to 1.4 sec) where measurements were taken, the 6-hr readings were smoothed using a 1/4, 1/2, 1/4 operator. This prevented excessive variations in ground-motion values due to small changes in period (which was only read to 0.2 sec).

Figures IV-6 through IV-8 show the variations of noise amplitudes with time. Estimates of the barometric pressure at the approximate center of the array (45°N 151°E) are included. The estimates were obtained from weather maps and readings made on the ship.

During Phase I, several periods of high microseismic activity were apparent. Between 27 and 30 October 1966, noise levels increased at all units, although the increase was much less pronounced for units on the seaward side of the Kurile trench. Increases also occurred between 1[illegible] and 15 November, 17 and 19 November, and on 22 November 1966 (again, less distinctly on the seaward seismometers). Unit 24 (S10) also showed increases between 26 and 29 November 1966 and on 30 November and 2 December 1966. During periods of high microseismic activity, low barometric pressures were observed in the region.

During Phase II, similar results were observed, although unit 21 (S7A) appeared somewhat erratic. Thus, the previously observed correlation between weather conditions and noise level[6] can again be seen.

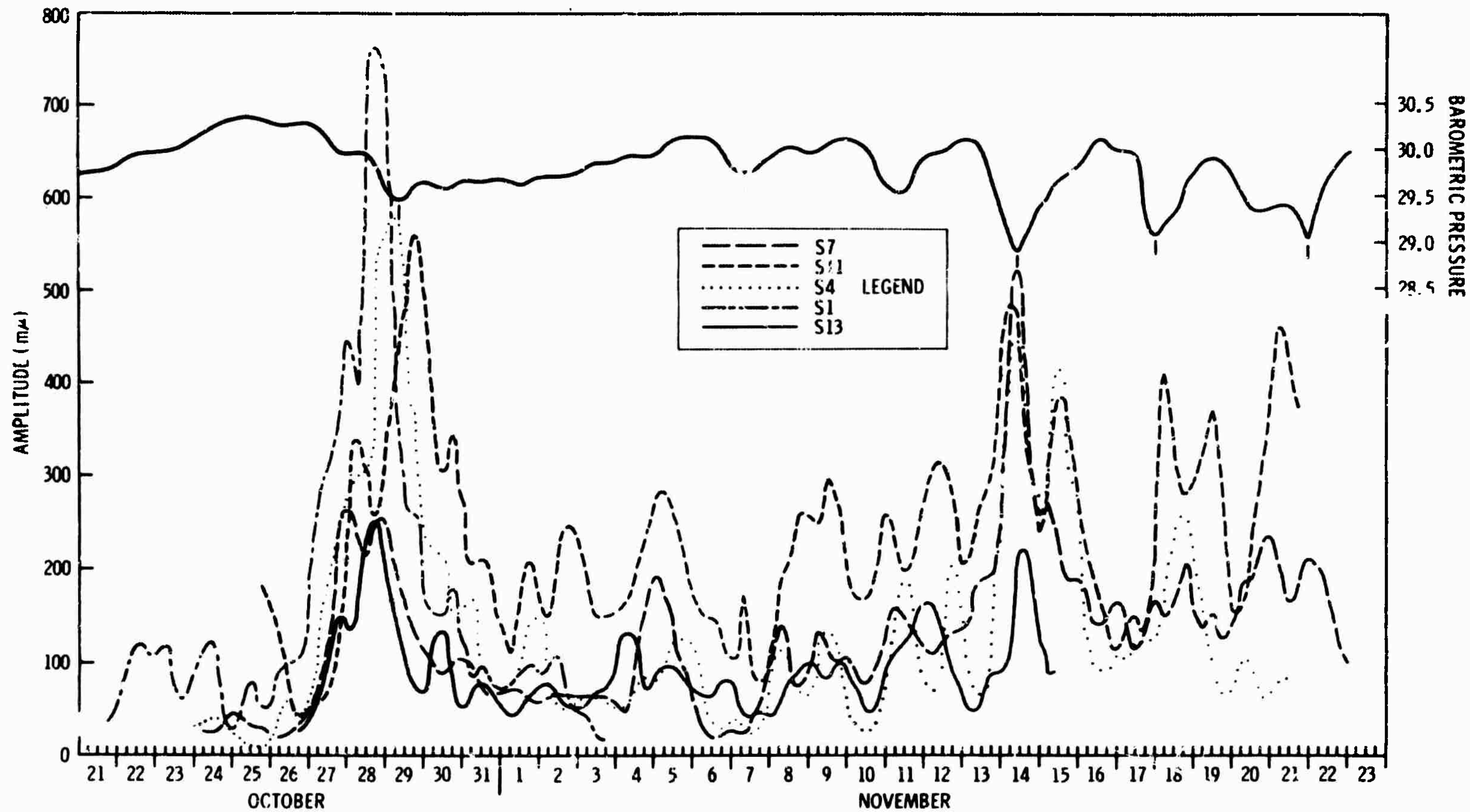


Figure IV-6. Variation in Noise Level on Seismometers on Island Side of Trench during Phase I

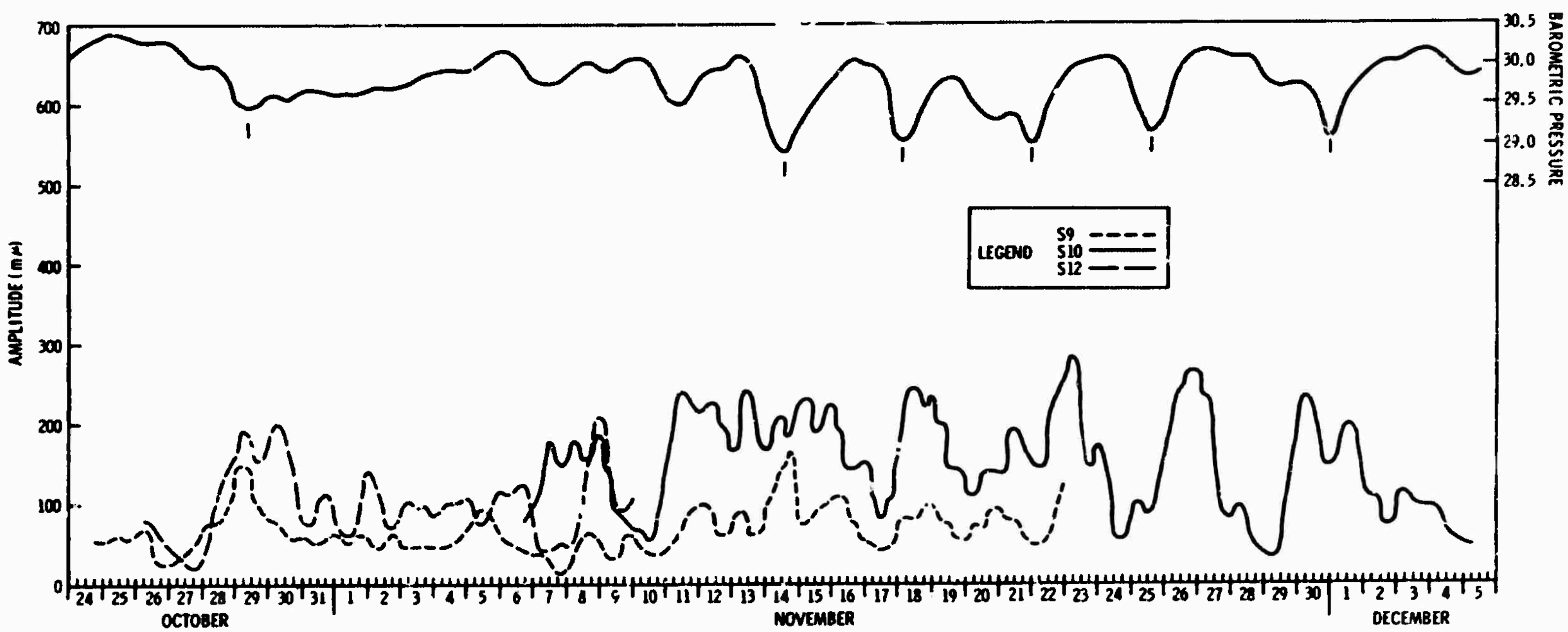


Figure IV 7. Variation in Noise Level on Seismometers on Seaward Side of Trench during Phase I

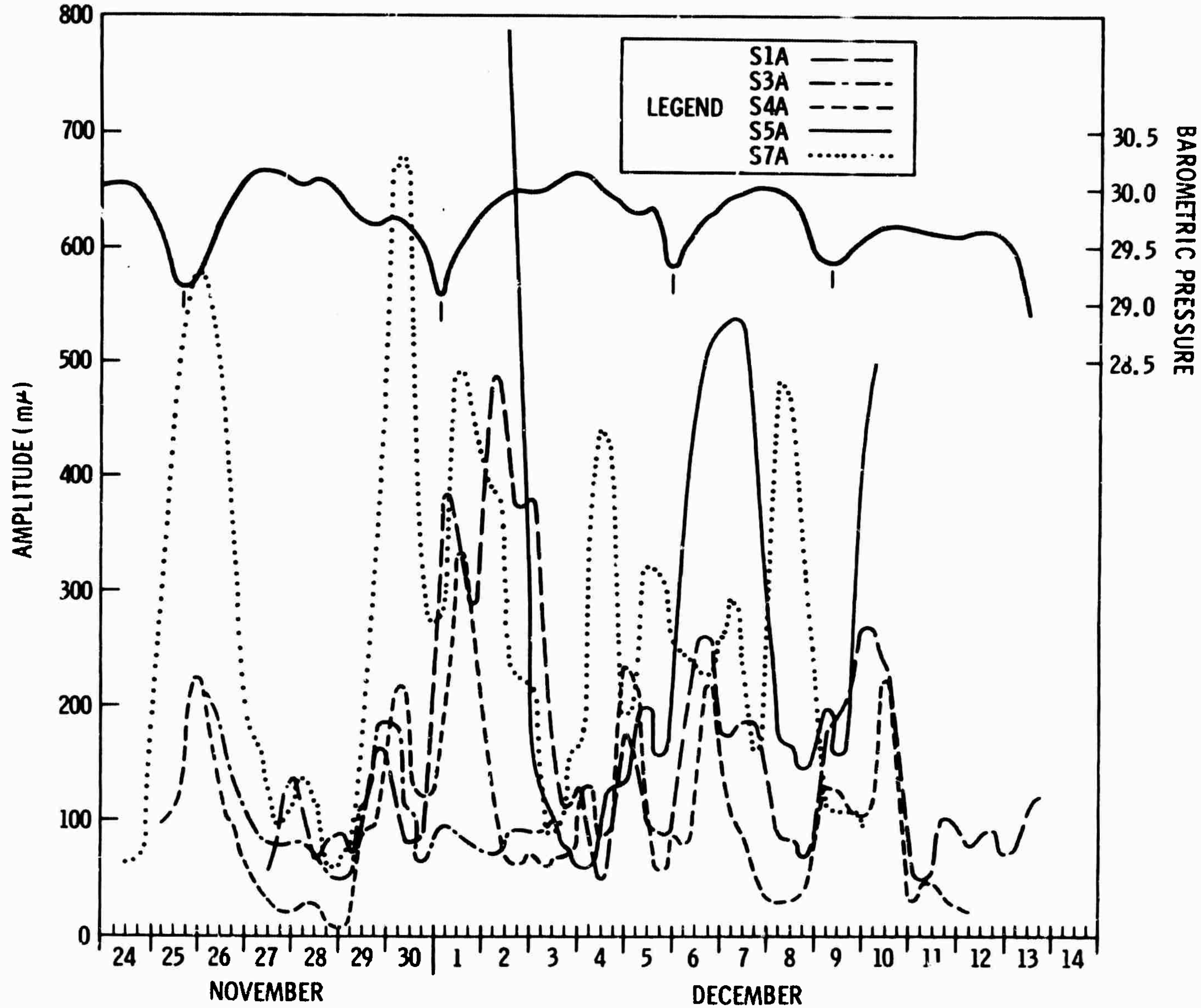


Figure IV-8. Variation in Noise Le' ' during Phase II

Table IV-3 lists the average noise amplitude at each unit. The large standard deviations reflect the effect of weather on the noise levels. There is considerable variation in the average level from unit to unit, which suggests that local bottom conditions influence the noise levels observed. However, because of the large variations due to weather conditions, larger samples would be needed to establish definitely the effect of local conditions.

Table IV-3

AVERAGE NOISE AMPLITUDE AT EACH STATION

Station No.	Average Amplitude (mμ)	No. of Readings	Standard Deviation	Comments
S7	129	120	82	
S13	92	80	45	Phase I, Island Side of Kurile Trench
S11	238	109	104	
S4	136	115	117	
S1	174	56	194	
S9	68	118	26	
S10	152	115	60	Phase I, Seaward Side of Kurile Trench
S12	95	60	47	
S1A	162	66	103	
S3A	102	30	40	
S5A	288	33	203	Phase II
S4A	102	69	69	
S7A	273	63	151	

SECTION V

REFERENCES

1. Texas Instruments Incorporated, 1967: Field Operation and Ocean-Bottom Seismograph Performance and Evaluation Kurile Islands Experiment, Ocean-Bottom Seismographic Experiments, Spec. Rpt. No. 1, Contract No. F33657-67-C-0105, 28 Apr.

2. Texas Instruments Incorporated, 1967: Explosion Program Kurile Islands Experiment, Ocean-Bottom Seismographic Experiments, Spec. Rpt. No. 2, Contract No. F33657-67-C-0105, 28 Apr.

3. Texas Instruments Incorporated, 1967: Bathymetry Program Kurile Islands Experiment, Ocean-Bottom Seismographic Experiments, Spec. Rpt. No. 3, Contract No. F33657-67-C-0105, 28 Apr.

4. Texas Instruments Incorporated, 1967: Preliminary Bulletin Kurile Islands Experiment, Ocean-Bottom Seismographic Experiments, Contract No. F33657-67-C-0105, 1 May.

5. Kosminskaya, I. P., S. M. Zuerev, P. S. Veitsman, Yu. V. Tulina, and R. M. Krakshina, 1963: Basic Features of the Crustal Structure of the Sea of Okhotsk and the Kuril-Kamchatka Zone of the Pacific Ocean from Deep Seismic Data, Bull. (Izvestiya) Academy of Sciences, U.S.S.R., Geophys. Ser., No. 1, p. 11-27.

6. Texas Instruments Incorporated, 1965: 30-Day Ocean-Bottom Seismograph, Aleutian-Kurile Operations, Final Rpt., Contract AF 19(628)-4075, 31 Oct.

APPENDIX A

ABSTRACTS FROM SPECIAL REPORTS

APPENDIX A

ABSTRACTS FROM SPECIAL REPORTS

Three special reports and a preliminary bulletin were written under Contract F33657-67-C-0105. Abstracts of each report appear in this appendix.

Special Report No. 1
Field Operations and Ocean-Bottom Seismograph Performance and Evaluation, Kurile Islands Experiment

A shallow-water test program and a deep-water operational program were conducted. The shallow-water tests environmentally checked the performance of 14 units which were not tested under the previous contract. Special tests of antenna design and temperature measurements were included. Of the 14 units checked, 13 were either fully operational or required minor corrections. One unit surfaced prematurely, floated inshore, and was damaged on the rocks. The unit was repaired under a new contract.

Deep-water tests were conducted adjacent to the Kurile Islands Arc to evaluate the seismicity of the area and the operational worthiness of the OBS and auxiliary equipment. Results of the seismicity study are summarized in a bulletin which is presented separately. Of 18 units dropped, 14 were recovered; of the 14 recovered, ... recorded for all or most of the time. The one unit which did not record was dropped to a depth greater than design specifications. The great pressure permanently distorted the sphere, pushing the shell against the recorder to prevent operation. However, this unit can be repaired. In general, the auxiliary equipment performed to manufacturers' specifications. The greatest problems were caused by the weather and the area of operations.

Special Report No. 2
Explosion Program, Kurile Islands Experiment

This report details the procedures developed for the explosion program and gives the reliability of the calibration program. The explosive used was 120,000 lb of high-energy composition B packed in 50-lb cubical cans, which was shot in ten 5.2-ton, six 1-ton, and one 1.5-ton packages. These charges were exploded in a network designed to provide optimum recording on the ocean-bottom instruments and minimum damage to marine life. The shots were restricted to the following conditions: daylight hours, 2 mi or more from any approaching vessel, a minimum of 1300 fm of water depth, and/or more than 100 km from land.

The operational procedure gave good data results.

The ship's rigging contributed greatly to the program's success. An A-frame and crane combination is recommended for future operations.

Special Report No. 3
Bathymetry Program, Kurile Islands Experiment

A bathymetric survey was conducted as a part of the Kurile Experiment (Ocean-Bottom Seismographic Experiments, Contract F33657-67-C-0105). Since the primary efforts of the experiment were directed toward the Ocean-Bottom Seismograph and Explosive Program, the method used during the bathymetric survey was appropriate but not optimum. Bathymetric data were very good and were as reliable as navigation would permit. However, the profile coverage was generally too sparse. The conclusion is that observations of depth values, OBS-environmental relations, and overall bathymetry are valid within navigational limits.

Preliminary Bulletin, Kurile Islands Experiment

An Ocean-Bottom Seismograph (OBS) field experiment was conducted during the months of October, November, and December 1966 in the Kurile Islands region. Data recorded by a total of 14 units are presented. Recorded during the experiment were 176 associated events, including 89 USC&GS reported events, 70 OBS preliminary epicenters and 17 calibration explosions detonated during the experiment. In addition, 200 assumed associated events were determined, with the number of stations per assumed event ranging from three to seven. These data are presented in standard bulletin format.

APPENDIX B

REVIEW OF PROGRAM PERFORMANCE

APPENDIX B

REVIEW OF PROGRAM PERFORMANCE

	Tasks	Status	Results	Recommendations
Field Operations	Install and operate a temporary network of 12 to 15 ocean-bottom seismographs for approximately 2 mo during the fall of 1966.	First array of 13 instruments was dispersed as planned. Second array was modified and decreased to five instruments.	Nine instruments from the first array were recovered. All instruments from the second array were recovered.	Navigational techniques must be improved for future operations and should include, in addition to Omega, Loran C and satellite navigation equipment. Large calibration charges should be assembled in prepackaged containers. A controlled experiment should be conducted to determine the validity of using small charges to determine seismometer orientation.
	Conduct a series of 10 to 20 large chemical explosions (1 to 5 tons) in the area to calibrate the network.	Seventeen charges were fired: six 1 ton, one 1.5 ton, and ten 5.2 ton.	All shots were fired without a misfire.	
	Conduct a series of smaller explosions as required to establish orientation of the horizontal seismometers.	No smaller charges were fired.		
Preliminary Data Review	Prepare film seismograms from magnetic-tape recordings.	Complete	Film copies of 14 magnetic-tape recordings were processed.	Studies to identify and isolate the resonant instrument-noise problem should be continued. Add back-up clock indications to magnetic tape along with existing digital-clock timing. Clean and repair units and equipment as reported. Modify digital clock to provide release choices of 1, 2, 4, 8, 10, 20, 30, or 40 days after reset time.
	Prepare a seismological bulletin containing a summary of the signals and associated events.	Bulletin submitted 1 May 1967	Analysis of the data revealed that 89 events reported by the USC&GS were recorded by the network, and 70 additional epicenters were determined. In addition, 200 assumed associated events were determined.	
	Include in the bulletin a detailed summary of operational periods and quality of data collected by individual stations in the network.	Complete	Results presented in Special Report No. 1 and bulletin.	
	Evaluate the performance of the ocean-bottom seismographs and make recommendations for any necessary modifications.	Complete	Unit performance and recommendations were reported in Monthly Report No. 6 and letter Proposal 118-SSD67.	
Special Analyses*	Make a complete analysis of data from the explosion program to determine the seismic velocities in the area of the ocean-bottom network.	All explosion recordings were analyzed and reported in the bulletin.	Analysis of first-arrival data from 17 explosions and 13 local earthquakes indicated an average crustal velocity of 5.4 km/sec and a mantle velocity of 8.1 km/sec in the Kurile region. Lack of detailed coverage prevented determining velocity variations in the region.	A sequence of controlled-refraction profiles should be established in the Kurile region to develop traveltime tables for locating local epicenters.
	Develop traveltime tables for locating local epicenters.	No attempt was made to develop traveltime tables.		
	Determine the location accuracy of local epicenters and the correlation between explosions and earthquakes located by the ocean-bottom network.	No attempt was made to establish confidence limits of epicentral positions.		
	Make a preliminary evaluation of possible source anomalies in traveltimes to teleseismic stations from the Kurile Islands area.	No evaluation of possible source anomalies was made.		
	Make standard visual noise measurements for film records as well as spectral measurements if the data justify the additional processing.	Amplitude and period measurements were made on all station recordings.	Noise levels were of the same order of magnitude as found in previous work. The levels increase over the whole region during periods of adverse weather (low-pressure disturbances).	A detail evaluation should be made of signal and noise recordings from each station with respect to topography, water depth, and weather.
	Correlate noise with weather patterns and differences dependent on location of instruments with respect to topographic features if practical.	Partially complete		
	Correlate epicenters determined by local network as compared to teleseismic networks.	No attempt was made to correlate local-epicenter determinations with teleseismic network.		Kurile epicenter data determined by local network should be correlated with teleseismic network to evaluate existing concepts of confidence-region determinations. Earthquake and explosion data should be processed to identify exact frequency content, signal duration, and relative energy content.
	Analyze signal characteristics of events in the Kurile Islands as observed by the ocean-bottom seismometers and their relevance to identification criteria.	No investigation was attempted.		
	Determine preliminary models of the crust and mantle structure of the Kurile arc and trench.	General model of structure was identified.		

*These studies were recommended with the understanding that analyses would not proceed without concurrence of the AFTAC Project Officer.

BLANK PAGE

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Texas Instruments Incorporated Science Services Division P.O. Box 5621, Dallas, Texas 75222	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP —

3. REPORT TITLE
FINAL REPORT – KURILE ISLANDS EXPERIMENT – OCEAN-BOTTOM SEISMOGRAPHIC EXPERIMENTS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Final Report

5. AUTHOR(S) (Last name, first name, initial)
McDermott, Joseph G. Linville, A. Frank Harley, Terence W.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
30 August 1967	42	6

8a. CONTRACT OR GRANT NO. F 33657-67-C-0105-P002 b. PROJECT NO. VELA T/6708 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) — 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) —

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
ARPA Order No. 624 Program Code No. 6F10	Advanced Research Projects Agency Department of Defense The Pentagon, Washington, D.C. 20301

13. ABSTRACT

An Ocean-Bottom Seismograph Kurile Islands Experiment, conducted between 21 October 1966 and 16 December 1966 under Contract F 33657-67-C-0105, had as objectives the determining of the operational worthiness of the OBS and the increasing of knowledge of seismic velocities, epicenter determinations, microseisms, and seismicity in the area of interest. All field objectives were accomplished as planned or modified to satisfy field conditions. OBS units are reliable self-contained, free-fall, remote-recall, deep-ocean instrument packages. Five-ton calibration charges can be packaged at sea and successfully deployed. All 5.2-ton calibration shots were well-recorded throughout the network. The bathymetric data indicate that the shelf margin and slope areas of the Kurile trench are more complex than previously mapped. Most events recorded by the OBS network were local or near-regional. Weather movements correlated with noise-amplitude fluctuations. Noise levels were of the same order of magnitude as found in previous work. Analysis of first-arrival data indicated an average crustal velocity of 5.4 km/sec and a mantle velocity of 8.1 km/sec in the Kurile region. More problems were caused by foul weather than any other factor.

DD FORM 1 JAN 64 1473

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Ocean-Bottom Seismograph						
Kurile Islands Experiment						
Seismic P-Wave Velocities						
Noise-Level Estimates						

INSTRUCTIONS

1. **ORIGINATING ACTIVITY:** Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (*corporate author*) issuing the report.

2a. **REPORT SECURITY CLASSIFICATION:** Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. **GROUP:** Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. **REPORT TITLE:** Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. **DESCRIPTIVE NOTES:** If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. **AUTHOR(S):** Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. **REPORT DATE:** Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. **TOTAL NUMBER OF PAGES:** The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. **NUMBER OF REFERENCES:** Enter the total number of references cited in the report.

8a. **CONTRACT OR GRANT NUMBER:** If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. **PROJECT NUMBER:** Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. **ORIGINATOR'S REPORT NUMBER(S):** Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. **OTHER REPORT NUMBER(S):** If the report has been assigned any other report numbers (*either by the originator or by the sponsor*), also enter this number(s).

10. **AVAILABILITY/LIMITATION NOTICES:** Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
____."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
____."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
____."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. **SUPPLEMENTARY NOTES:** Use for additional explanatory notes.

12. **SPONSORING MILITARY ACTIVITY:** Enter the name of the departmental project office or laboratory sponsoring (*paying for*) the research and development. Include address.

13. **ABSTRACT:** Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. **KEY WORDS:** Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.